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Improvement of the Output Characteristics of a Relativistic Magnetron using a Small Diameter Cathode Surrounded by a Transparent Cathode

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Conventional magnetrons in which cathodes with thermionic and/or secondary electron emission are used operate poorly when the ratio of the anode-to-cathode radius is large, $R_a/R_c > 2 \sim 2.5$, because of unfavorable starting conditions and strong mismatch of the synchronous particle-field interaction. The field of the operating mode, which decreases exponentially from the resonant system cavities to the cathode, becomes too weak on the electron flow rotating over the cathode to capture electrons to the anode. On other hand, the azimuthal drift velocity of electrons is inversely proportional to radius, $v_e \sim r^{-1}$, whereas the phase velocity of the wave has the opposite tendency, $v_{ph} \sim r$, and the electron space charge field promotes synchronism $v_e \approx v_{ph}$ in the total interaction space when the gap between electrodes is narrow [1, 2]. However, for a magnetron with a small R_c, mismatch of the synchronism becomes so large that the appearance of additional electron drift leads to strong deformation of electron spokes, and even to the disappearance of the anode current I_a [3].

In relativistic magnetrons in which, as a rule, cathodes with explosive electron emission are used, two factors can promote synchronism in the wider interaction space: i) stronger space charge and ii) the azimuthal magnetic field $H_\theta = 2I_z/cr$ of the axial cathode current $I_z = I_a + I_{end}$ (I_{end} is the leakage current leaving the magnetron in the axial direction) that can change the dependence of the electron's azimuthal drift velocity on radius through $v_e = UH_{0z}/\left(H_z^2 + H_\theta^2\right) r \ln(R_a/R_c)$, especially for low impedance magnetrons.

However, recent computer simulations using the three-dimensional code ICEPIC [4] for averaged radial distributions of space charge Q, radial electric field E_r, and azimuthal velocity of electrons v_θ (Fig. 1 left), for the magnetron described in [5] where $R_a/R_c > 5$, show that phasing of electrons with the operating $\pi-$mode cannot be provided in such a cylindrical interaction space in spite of the aforementioned improved conditions for synchronous interaction in relativistic magnetrons; that is, such a magnetron can not demonstrate high output characteristics.

Additional longitudinal strips arranged on a cylindrical surface over the small diameter cathode (Fig. 2) with the same cathode potential were included in a new design. They not only improved the start conditions (because these strips act as the cathode which is transparent for *TE* modes [6] and thus provides a strong electric field of the synchronous wave on the electron flow near this cathode), but also provide synchronous interaction practically in the entire interaction space, as shown from calculated distributions of Q, E_r and v_θ (Fig. 1 right). (It is easy to infer from this figure that electrons rotate in the interaction space with frequency $\omega_e = dv_\theta/dr$, which is approximately equal to frequency $\omega_{ph} = 2\pi f/n$ of the phase rotation of the operating $\pi-$mode with azimuthal index n = 3 and operating radiation frequency f = 1 GHz).

This cathode leads to a significant improvement in the output parameters of the magnetron (efficiency and radiation power (Fig. 3)) for an appropriate selection of the radius R_{strip} of the transparent cathode, in addition to providing faster start of oscillations than the techniques of cathode [7] and magnetic [8] priming alone.

References

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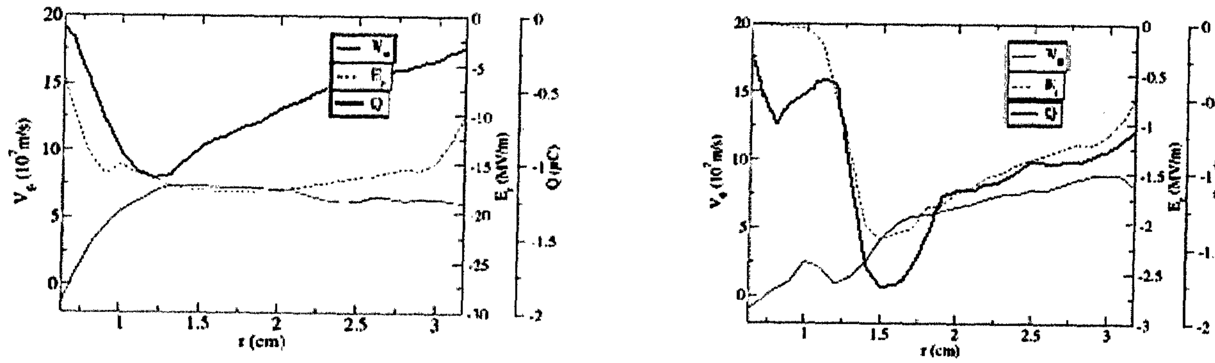

Fig. 1. Averaged radial distributions of space charge Q, radial electric field E_r, and azimuthal electron velocity v_θ in a magnetron [5] with inner solid cathode with radius $R_c = 0.6$ cm (left) and with additional transparent cathode with radius $R_{strip} = 1.4$ cm (right).

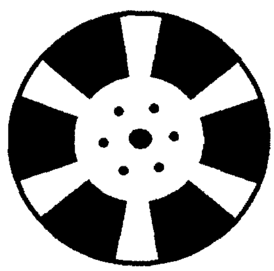

Fig. 2. Magnetron with additional transparent cathode.

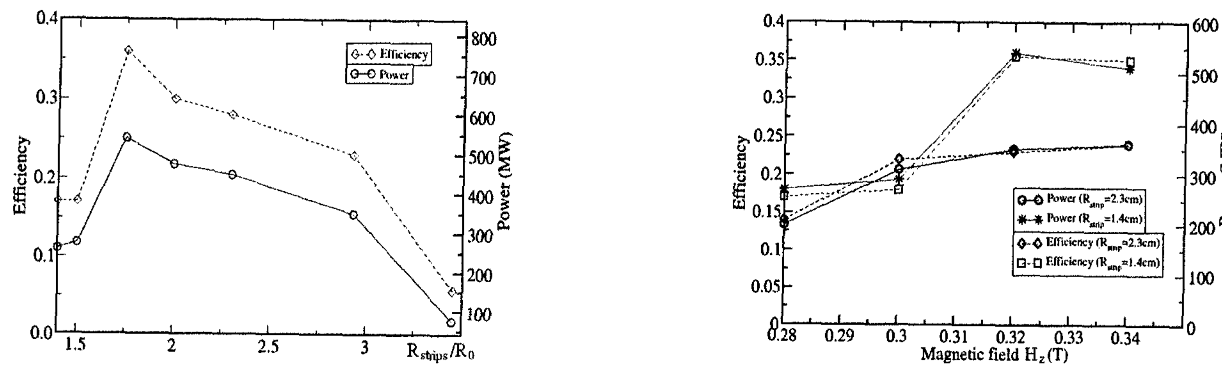

Fig. 3. Dependences of radiation power and electronic efficiency on position of cathode strips when axial magnetic field H_z = 3.2T (left) and on magnetic field for two different R_{strip} (right).